Chap. 5:consolidating the transportation system (1922-1937) : railroads

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With these factors as background, all areas of Japan developed tourism and the private transit corporations played an important part in providing the way to the tourist destinations. Transportation companies in these areas promoted tourism, well aware of how important tourists were in creating transit demand. Many private railroad companies spread their networks and facilities out into areas where the best scenic spots and cultural assets were located and adopted operational guidelines that sought to monopolize all train and bus routes in these regions. These were features of the rapid progress made in laying railroads to connect urban areas with scenic locations. Two important examples of urban private railroads in this connection are the Tobu Railway, which develped the Nikko-Kinugawa region, and the Keihan Electric Railway, which developed the area around the shores of Lake Biwa. Similar actions were taken by private railways not located in the major urban areas, such as the Nagano Electric Railway's development of Shiga Highlands and the Fuji-Sanroku Electric Railway's development of the region extending out from the north face of Mount Fuji.

The National Railways was also interested in tourist transportation and began operating through trains between the cities and the resort areas, even selling discount tickets to promote their services.

Notes

1. Nakagawa Seisa, *Teikoku Tetsudō seisaku ron* (Imperial Railroad policy) (Tetsudo Shunju Sha, 1928), p. 34.
2. Kinoshita Yoshio, *Kokuyū Tetsudō no shōrai* (The future of the National Railways) (Tetsudo Jiho Kyoku, 1924).

Railroads

Eiichi Aoki

Developing an Independent Rolling-stock Technology

The National Railways had started, in 1909, standardizing and domestically producing steam locomotives and was gradually moving ahead in this area during the period under study. However, the vastly increasing demand for transportation during the period required the design and construction of larger and more powerful locomotives as well as of larger passenger coaches. Plans were also moving ahead to standardize steam locomotives for use in many different applications, and engines were being developed for the very diverse types of railroading peculiar to Japan. Locomotives powered by electric motor and by internal-combustion engines were also being domestically produced and standardized during this period. The body construction of freight and passenger cars and electric and petrol-burning cars was being changed over from all-wood construction to one in which body frame and exterior walls were of steel and the inside walls of wood.

The 1920s and 1930s, when the locomotives used on the trunk railroads were developed, was one of the golden periods for the progress of railroad rolling-stock and engines in Japan. The Seiyukai cabinet, the most aggressive advocate of expanding the railroads into every corner of the country, put an end to, in 1918, the policy for changing the nation's tracks to standard gauge ongoing since 1910. From then on, it was decided, the nation's burgeoning railroad transport power would have to ride on narrow-gauge rails. This abandonment of standard gauge placed very severe technical restrictions on the National Railways' engineers in designing railroad rolling-stock. The lack of wider gauge was a major factor preventing improvements in the design and performance of powerful locomotives.

Steam Locomotives

The first generation in standard-model locomotives mass-produced from the middle 1910s to the 1920s consisted of the 8620 (a passenger-train locomotive with the 1C wheel arrangement, or 2-6-0, i.e., two pilot wheels on the pony trucks, six drive wheels, and no trailer trucks) and the 9600 (type 1D) [2-8-0], for freight hauling). During the period under study, the second generation of more powerful standard-model locomotives appeared. For example, the locomotive for passenger use was the 18900 (renamed the C51 in 1928), of which 289 were produced from 1919 to 1928, and that for freight, the 9900 (renamed the D50 in 1928), of which 380 were built from 1923 to 1931. The 18900 was designed for hauling express passenger trains on the trunk railroads. It was a 2C1 type (4-6-2, Pacific) and could be equipped with a large firebox. The drive wheels on this model had a diameter of 1,750 mm, bigger than the largest diameter – 1,600 mm – on previous passenger locomotives. At the time, they were the largest wheels in the world on the 1,067-mm gauge track. The axles weighed 14.2 tons, about 1 ton heavier than previous locomotives, but this was made possible because at that time the rails on all trunk railroads in the nation were being changed over to 37 kg rails.[1] All pre–World War II passenger-train locomotives on National Railway trunk lines had the 2C1 wheel arrangement and 1,750-mm diameter drive wheels, which had been started with the 18900. The fireboxes in the 9900 freight locomotive had been made bigger, and, consequently, the wheel arrangement was modified to the 1D1 type (2-8-2, Mikado), and the wheel diameter was increased from the 1,250-mm on the 9600 to 1,400 mm. The 14.9-ton axle load limited the 1D1's use to the trunk lines.

The National Railways imported a three-cylinder locomotive during this period; in 1926, it purchased six of these model 8200s from the American Locomotive Company, which it renamed the C52 in 1928. The National Railways used the structure and operational performance of these six models for reference in designing the C53 locomotive, and produced 97 of them from 1928 to 1931. The C53 was used for express passenger service on the Tokaido and San'yo trunk lines and had a 2C1 (4-6-2, Pacific) wheel arrangement that was the same as the C51, and an axle load of 15.4 tons, heavier than any other locomotive so far. In 1928, a project began to

Table 1. Number of locomotives by type (1872–1983)

End of fiscal year	Steam	Electric	Internal combustion (diesel or gasoline) engines
1872	10		
1882	47		
	(1883) 7		
1892	133		
	185		
1902	431		
	974		
1907	1,924		
	111		
1912	2,361	12	
	364		
1922	3,642	29	
	797	38	33
1932	3,953	131	10
	858	185	69
1942	5,115	239	11
	587	196	30
1947	5,933	350	0
	552	195	27
1952	5,066	399	3
	372	246	61
1962	3,601	931	335
	136	302	177
1972	809	1,918	1,793
	18	296	200
1982	5	1,703	2,051
	6	202	204
1983	5	1,613	1,989
	6	180	191

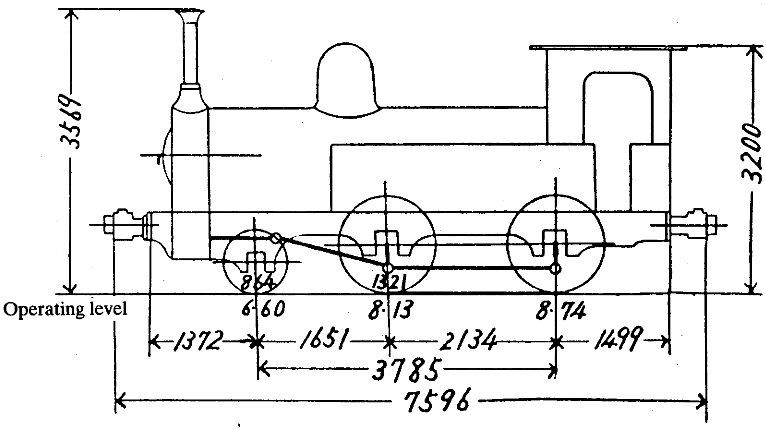
Source: Harada Katsumasa, *Tetsudō no kataru Nihon no kindai* (The railroads and Japanese modernization), expanded and rev. ed., p. 245, table 9 (more recent data have been added).
Note: The upper row of the double sets of figures is for the National Railways, the lower row for the private railroads. The figures for private railroads include tram locomotives.

change over all tracks on the Tokaido and San'yo trunk lines to 50-kg rails to make the operation of the C53 possible. The use of narrow gauge required that the centre crank on the three-cylinder locomotive, a theoretically superior type, push down into a narrow space. Its mechanisms were complicated, so much so that they were a constant headache for the repair crews. The C53 was the only domestically produced three-cylinder model, but the limitations in the use of this locomotive required that its successor,

Fig. 3. Major locomotives

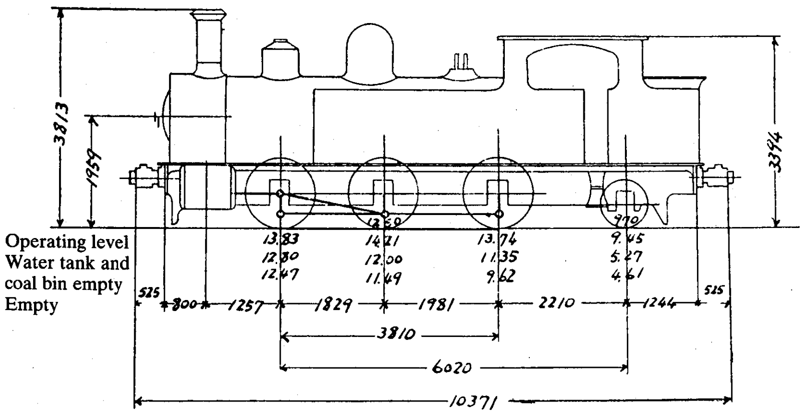
A. Major steam locomotives in Japan

Model 150



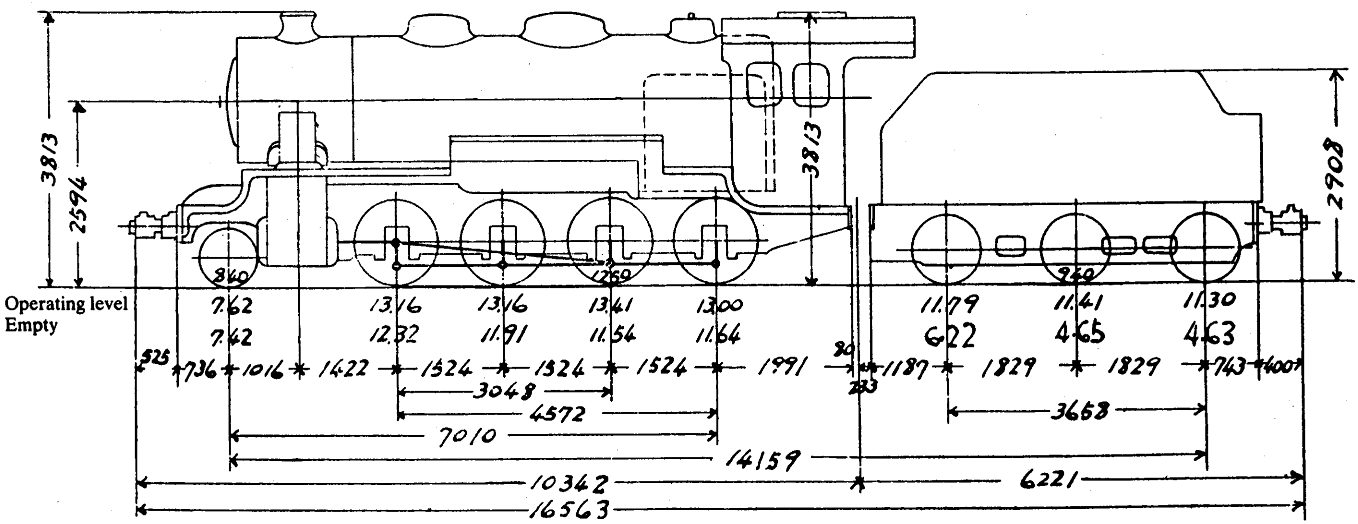
One of 10 locomotives imported from Great Britain and used on the railroad that began service in 1872 between Shimbashi and Yokohama. At the time it was called Locomotive No. 1. Built by the Vulcan Foundry. Weight, 23.5 tons; drive-wheel diameter, 1,321 mm. Now on display at the Transportation Museum, Tokyo.

Models 2100, 2120



A total of 285 were built in Great Britain and at Kobe Works in 1890–1905 for use on steep grades. During the Russo-Japanese War, in particular, factories in Germany and America built locomotives of the same model – 75 of model 2400 were built in Germany and 150 of model 2500 were built in America. Weight 49.2 tons; drive-wheel diameter, 1,245 mm. Widely used up to the Second World War.

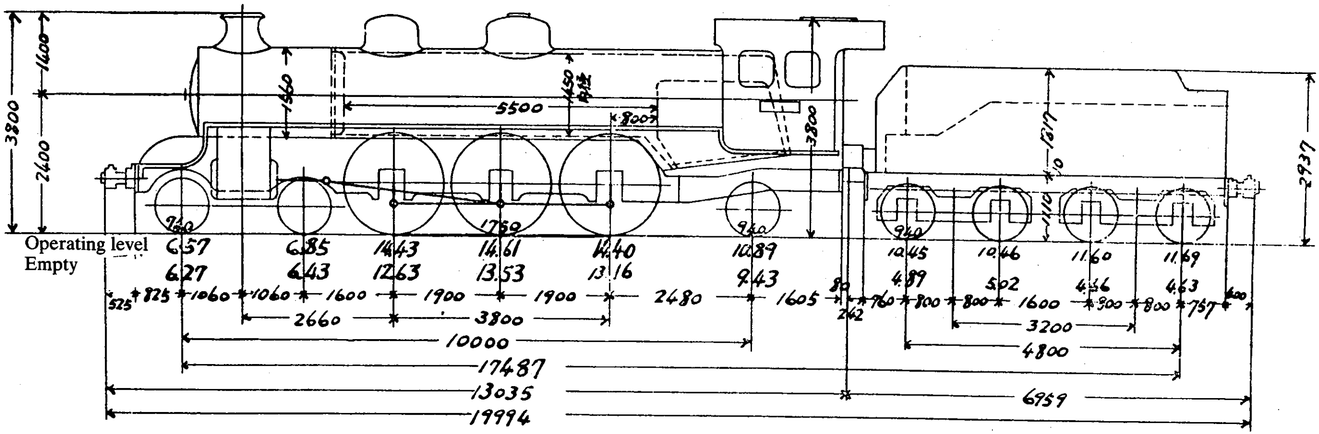
Model 9600 superheated steam locomotive



Locomotives were domestically produced and standardized after the completion of railroad nationalization, and 770 of model 9600 were produced as the standard for freight hauling from 1913 to 1926. Weight, 60.4 tons; drive-wheel diameter, 1,250 mm. Widely used until 1976.

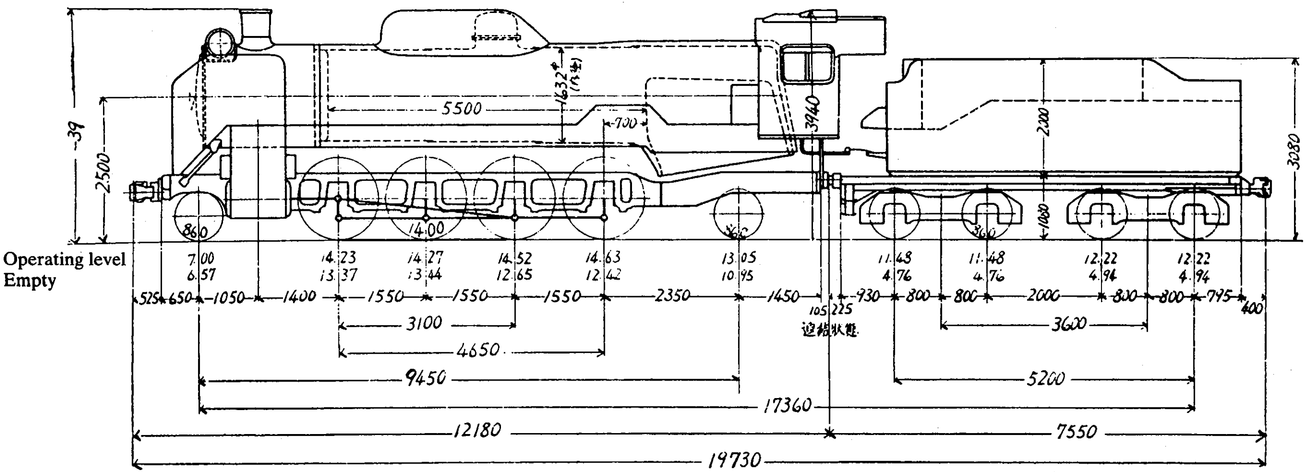
Fig. 3 *(continued)*

Model C51 superheated steam locomotive



To beef up transportation power after the First World War, 289 of these locomotives were built from 1919 to 1928 for use in hauling high-speed passenger service trains on the trunk lines. Uses the 2C1 (4-6-2, Pacific) wheel arrangement and 1,750 mm, large-diameter wheels, which were adapted to succeeding passenger locomotives in Japan. Weight, 66.3 tons.

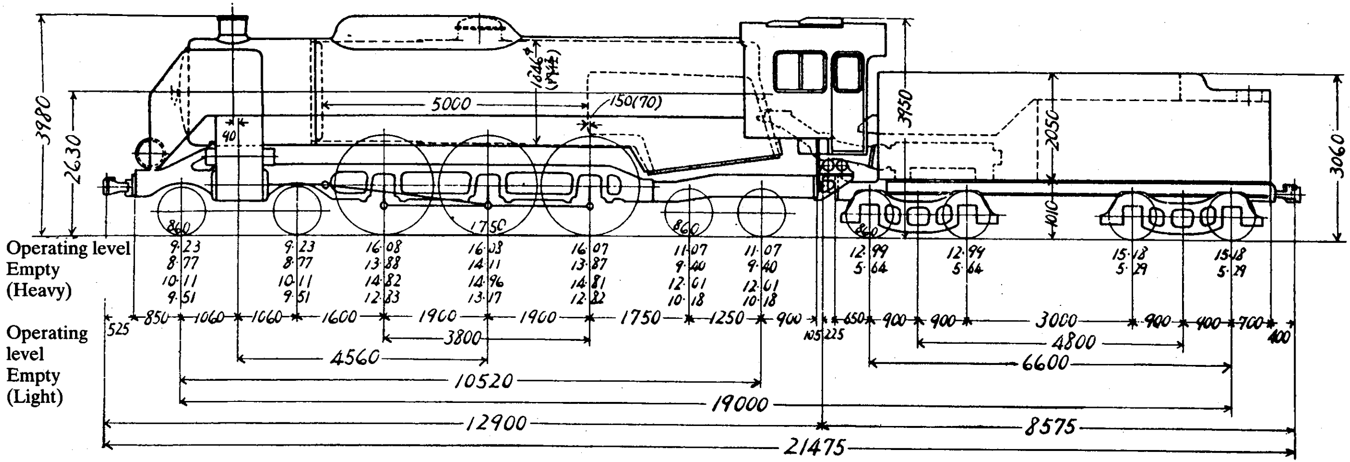
Model D51 superheated steam locomotive



This locomotive was used for freight hauling and on steep grades, with 1,115 built from 1936 to 1945 to strengthen transport power during the economic recovery of the latter half of the 1930s and the Second World War. More steam engines of this type were built in Japan for private railways and for export than any other. It has also been used in Taiwan and the Soviet Union (exported to Sakhalin after the Second World War). Weight, 76.8 tons; wheel diameter, 1,400 mm. This drawing is of the second model built from 1938 to 1944.

Fig. 3 *(continued)*

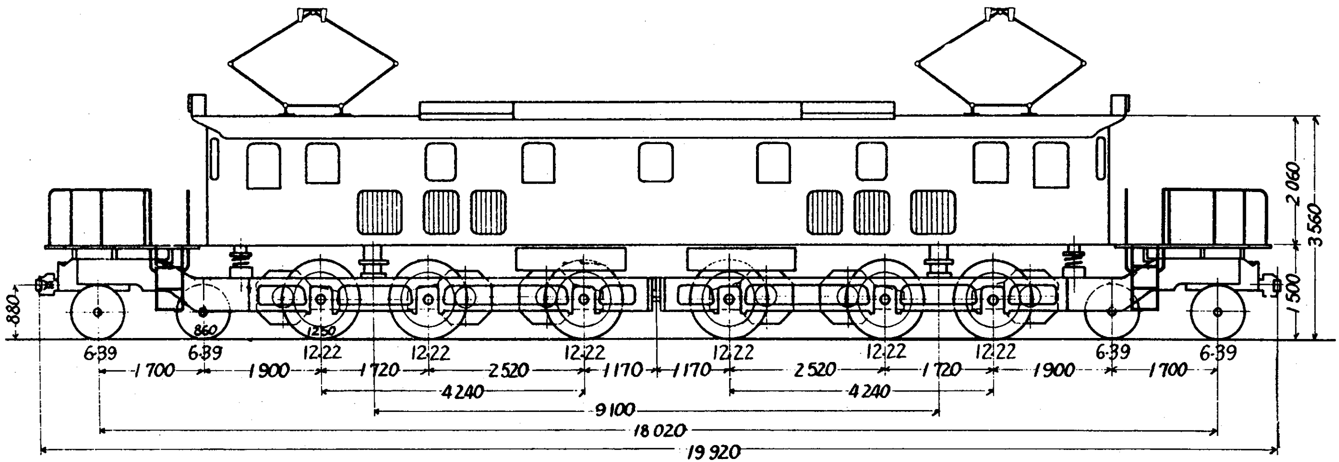
Model C62 superheated steam locomotive



Forty-nine of these locomotives were built in 1948–1949 for high-speed passenger hauling on the trunk railroads. The locomotive was built by transferring the boiler from the large D52 freight locomotive designed during wartime. It was the largest and the last of the high-speed passenger steam engines built in Japan. Weight, 88.8 tons; drive-wheel diameter, 1,750 mm.

B. Major electric locomotives in Japan

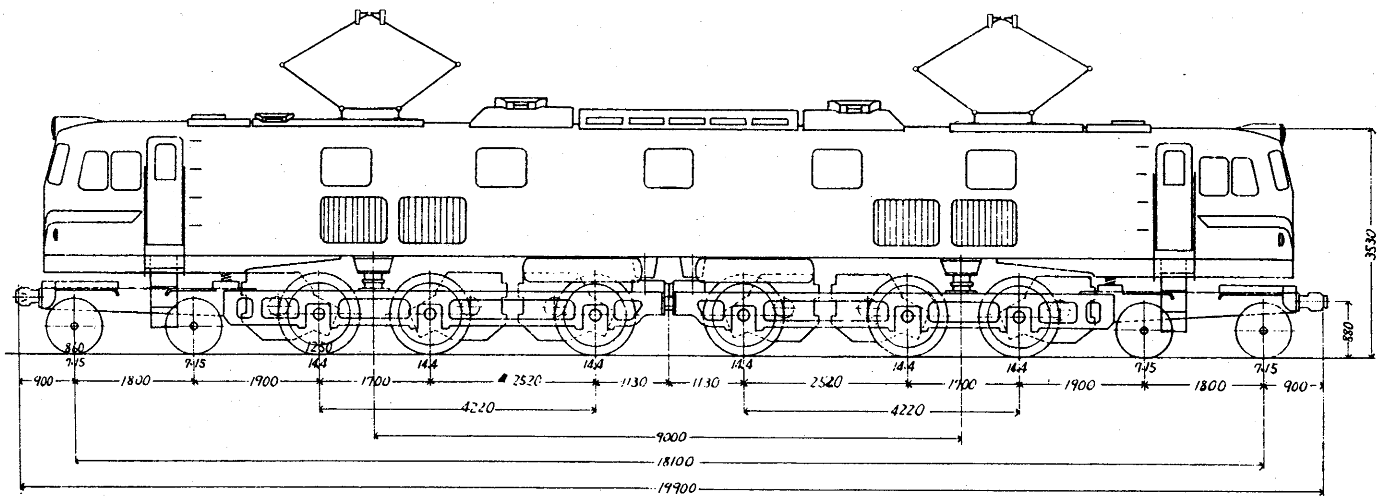
Model EF53 DC electric locomotive



Electric locomotives were domestically produced and standardized just after the electrification of the Tokaido trunk line (1925). After the EF52 test model was built in 1928, 19 EF53s for passenger-train use were produced in 1932–1934. Weighs 98.9 tons and has a rated one-hour output of 1,350 kilowatts.

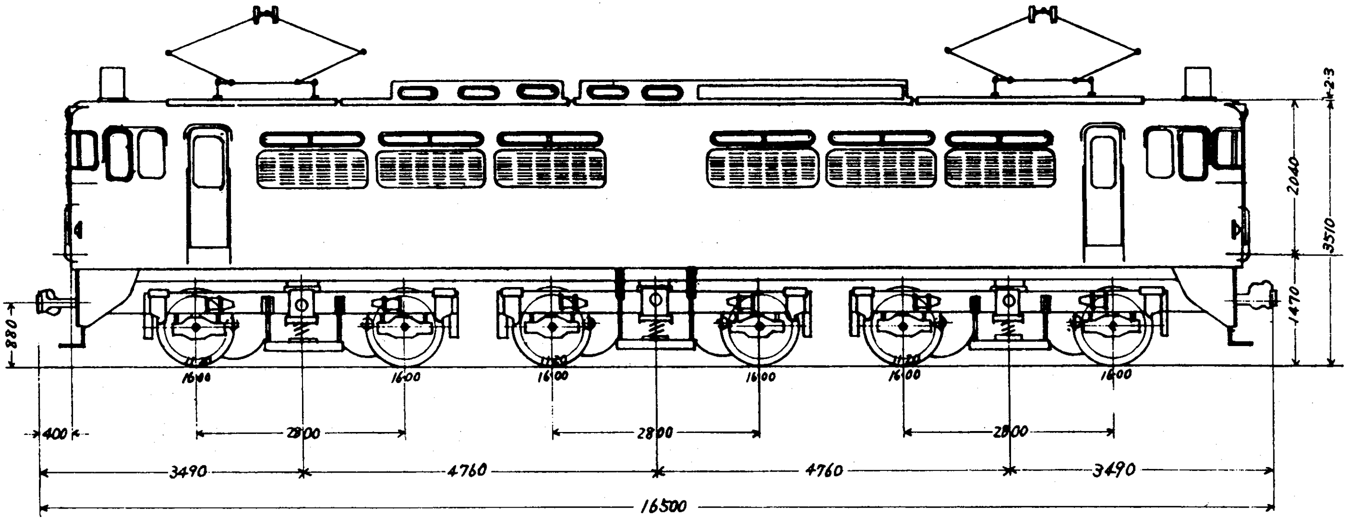
Fig. 3 *(continued)*

Model EF58 DC electric locomotive



These locomotives for passenger-train use were mass-produced for operation on the trunk railroads that were being rapidly electrified after the Second World War. From 1946 to 1957, 172 were produced. Weighs 115 tons and has a rated one-hour output of 1,900 kilowatts. The first models had a square-shaped body with attached deck, but those produced after 1951 had a more streamlined body like the one shown in the diagram. The original models were converted over to this body shape in 1952.

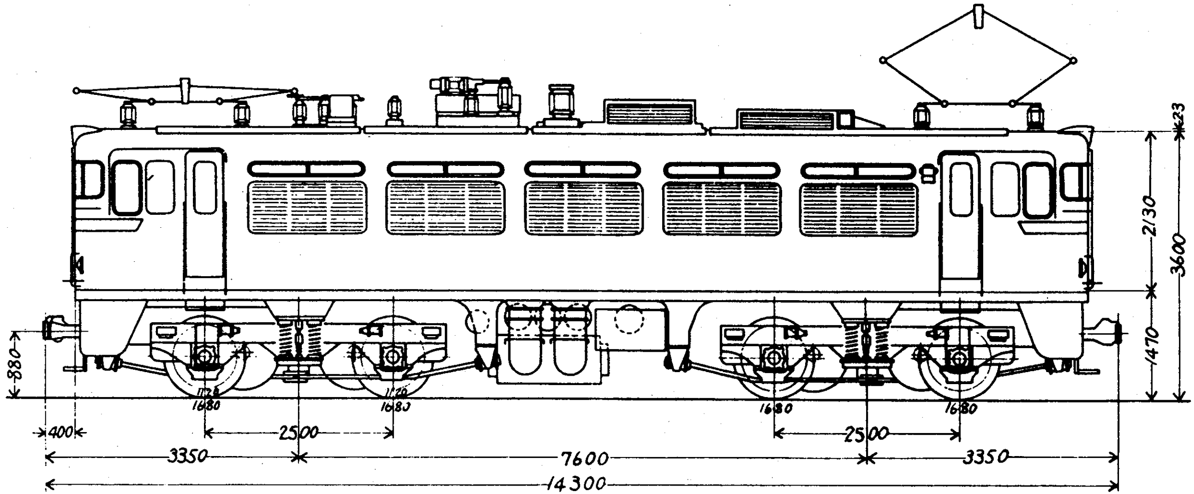
Model EF65 DC electric locomotive



Beginning in 1958 National Railway electric locomotives were provided with high-speed motors, their output was strengthened, and they were equipped with control methods in using a wide range of weak fields. The EF65 was developed for high-speed passenger use in flat areas. A total of 308 were built from 1965 to 1979. Weight, 96 tons; rated one-hour output, 2,550 kilowatts.

Fig. 3 *(continued)*

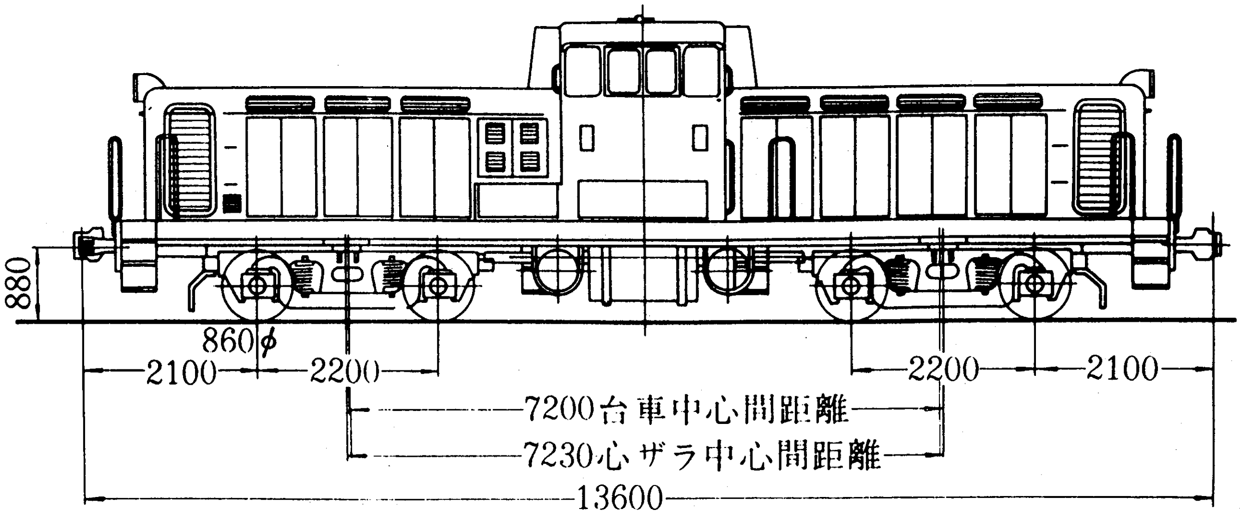
Model ED75 AC electric locomotive



This model was the result of experience gained in operating alternating-current locomotives after 1955. Uses silicon rectifiers. A total of 302 of these locomotives were produced in 1963–1976. This is the standard model AC locomotive; more of these were built than any other. Many variations according to the terrain in which it is used. Weight, 67.2 tons; rated one-hour output, 1,900 kilowatts.

C. Major diesel locomotives in Japan

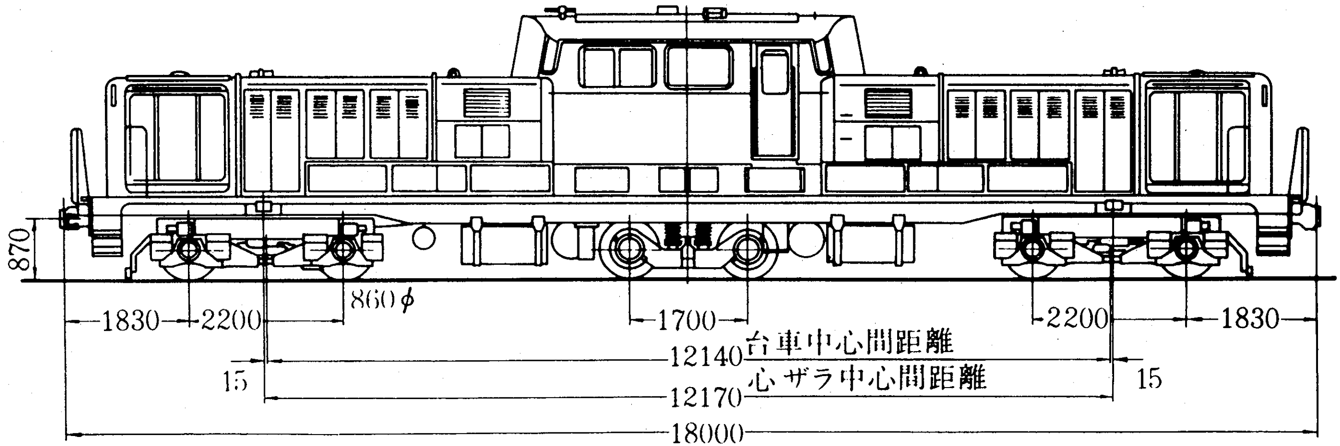
Model DD13 diesel hydraulic locomotive



Developed for use in both yard-switching and passenger-train hauling on branch lines. From 1957 to 1966, 416 were built. This is the first diesel locomotive in Japan that made it through the test stage to mass production and full-scale use. Weight, 56 tons; consecutive rated output, 740 hp (1,000 hp on units produced after 1960). This diagram shows the first model, built in 1957.

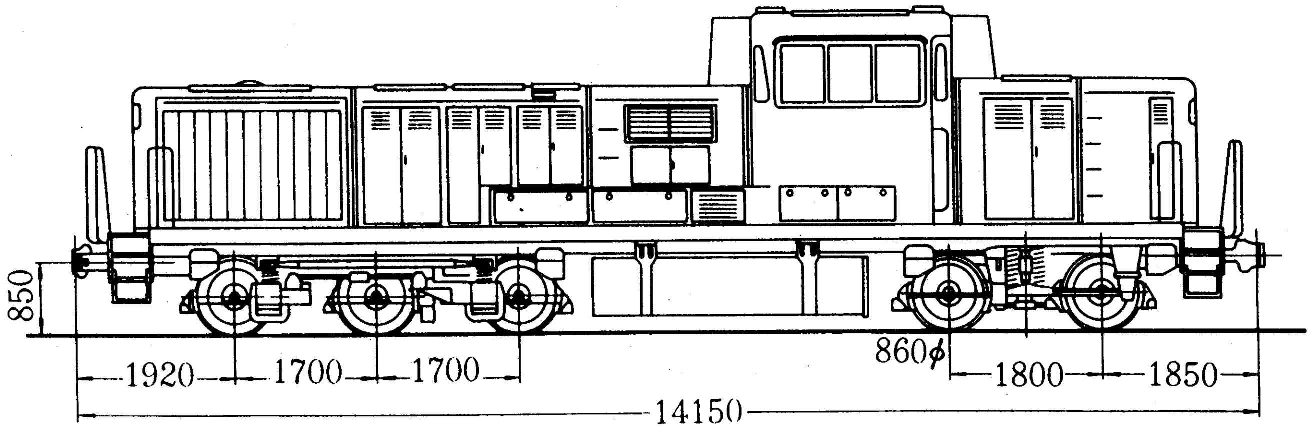
Fig. 3 *(continued)*

Model DD51 diesel hydraulic locomotive



Developed for trunk-railroad use, 649 were built from 1962 to 1978. Axle load lightened to 14 tons so that it can be used on lines where track construction is of a lower level. The appearance of this model made possible the replacement of steam engines with diesel. Total weight, 84 tons; consecutive rated output, 2,000 hp (models built after 1964 were of 2,200 hp). This diagram shows the models that were built after 1964.

Model DE10 diesel hydraulic locomotive



Developed as a locomotive for hauling on branch lines and for yard-switching. Features a reduction in axle load to 13 tons through the use of five drive axles. A total of 707 were built from 1966 to 1978. More of these diesel locomotives were built in Japan than any other. Weight, 65 tons; rated output for one hour, 1,250 hp (all models built from 1969 on were of 1,350 hp).

the C59, which began construction in 1941, be the usual two-cylinder locomotive.

The C54 (17 built in 1937), the C55 (62 built from 1935 to 1937), and the C57 (201 built from 1927 to 1947) were improved versions of the C51; they were passenger-train locomotives with axle loads of 14 tons and were widely used on trunk railroads. Although the locomotives in this series were similar to the C51, their redistributed axle load reduced both maximum axle load and the weight on drive wheels, which, together with improved boiler pressure, gave greater tractive power than the C51.

The recession of the latter 1920s lowered demand for freight transport and caused production of the D50, a locomotive for freight hauling, to be stopped in 1931, with no more being built for a while. Production on the D51 began in 1936. The D51 was the same as the D50 in having a 1D1 wheel arrangement (2-8-2, Mikado) and a wheel diameter of 1,400 mm. Revision in the distribution of weight on the axles lightened the maximum axle load (14.3 tons) and the weight on the drive wheels. This allowed the locomotive to be used in a wider range of areas. Increased boiler pressure gave it almost the same tractive power as the D50. (The development resembled that of the C55–57 series in its development out of the C51). Mass production of the D51 increased at the same pace as the demand for freight hauling during World War II. By 1945, five private manufacturers and six National Railway factories had turned out 1,115 D51s, including those produced in the latter period of the war. The D51 was the most numerous of any of the National Railway locomotives and hauled freight on all trunk and branch lines in the country. It was often used in passenger and freight service in areas with steep grades.

Small, lightweight tank locomotives (no separate tender) were built for hauling short, semi-express passenger trains and short-distance freight, and for lines where lower standards were used to construct tracks. The first of these was the C10, 23 of which were built in 1930. This model was further lightened and its axle load reduced to develop the C11 (1C2 type [2-6-4]) and C12 (1C1 [2-6-2]) that were produced beginning in 1932 for use on rural branch lines. Railroads constructed in rural areas required a lightweight locomotive with tender that had an operating range of about 100 km. The C56 was built for that purpose beginning in 1935. From 1937 on, the C58 was built as a middleweight locomotive for operation on branch railroads. Increased boiler pressure gave the C58 very powerful tractive force for its weight.

Looking at the progress the National Railways made in developing standard locomotives in the latter half of the 1920s and into the 1930s, we can see that in addition to the obstacles created by narrow gauge, the pre–World War II lack of thorough improvements in roadbed structure and bridges prevented the building of locomotives with a maximum axle load on drive wheels greater than 15 tons. Although the steam locomotives of Europe and North America were making earth-shaking progress in upping their speed and tractive power, restrictions of axle load prevented Japanese trunk-railroad locomotives from being made larger. The lack of adequate improvements in boiler pressure, because of the need for lighter weight, also kept Japanese locomotive performance below world levels. Cancelling the plan to reconstruct the nation's tracks to standard gauge immediately constricted railroad transportation power, putting the trunk lines behind the rest of the world.

Electric Locomotives

The National Railways had, since 1912, been operating electric locomotives on the Shin'etsu Main Line between Yokokawa and Karuizawa, a section that was equipped with APT system rack-rails (steepest gradient 68‰). It had also successfully produced them domestically since 1919, but they were only for special uses. The private Osaka-Koya Railway manufactured the first domestic electric locomotive at its Sakai Higashi factory in 1916, but used it only on part of its railroad.

In December 1925, the routes between Tokyo and Kozu on the National Railway Tokaido Line and between Ofuna and Yokosuka on the Yokosuka Line were electrified, and electric locomotives began hauling passenger trains. To take advantage of advanced foreign technology, electric locomotives were imported in three stages from 1922 to 1926. Imported at this time were 47 units of 8 types of locomotive for passenger use and 12 locomotives of 5 types for freight use. Broken down by country of origin, there were 43 locomotives from Great Britain, 10 from the United States, 4 from Switzerland, and 2 from Germany. Each locomotive differed greatly from the others in performance and mode of operation, and the problems in getting spare parts were horrendous.

The National Railways gathered data on the imported locomotives and worked with four manufacturers – Kawasaki Sharyo, Mitsubishi Electric, Shibaura Seisakusho, and Hitachi, Ltd. – to design a standard electric locomotive for passenger use. The result of this collaboration was the building of the EF52 in 1928. The prototype had a 2C + C2 wheel arrangement and six 225-kilowatt DC series-wound motors. However, only nine EF52s were built, including the modified 1931 model. But the EF52 had a long line of progeny: for passenger use, 19 EF53s were built in 1932–1934; 3 streamlined EF55s were built in 1936; 12 EF56s, equipped with a small steam boiler for heat, were built in 1937–1939; for freight use, 41 EF10s were built in 1934–1941, and 4 EF11s, with electric regenerative braking, were produced in 1934–1936. All had six 225-kilowatt motors. Eighteen ED16s, a smaller version, were built in 1931 and used on mountainous lines such as the Chuo Main Line between Iidamachi and Kofu and on the Joetsu Line between Minakami and Ishiuchi. Twenty-eight ED42s were built as a standard model between 1931 and 1947 for use on the APT-system rack-rail routes between Yokokawa and Karuizawa.

Even though the electric locomotives were standardized in this manner, their production was far less than that of the steam locomotive. This was because there were only a few lines of the National Railways at that time that were electrified and could accommodate these locomotives.

Private railroads operated more domestically produced electric locomotives, but they had no large six-drive-axle models like the National Railways; most were small with a B + B wheel arrangement.

Internal-combustion Locomotives and Railcars

The use of internal-combustion engines for motive power spread rapidly during this period, and one regional private railway after another bought and began operation of gasoline-powered railcars to compete with the buses. The National Railways also began to use large numbers of gasoline-engine railcars for short-distance passenger service in the urban peripheries and other rural areas of the nation.

The internal-combustion engines used by the railroads in the previous period were hot-bulb engines developed for fishing boats and agricultural product processing machines. They were sufficient in neither performance nor reliability. But the engines in this period were developed for motor vehicles, and though most at first were of low output, around 20 horsepower, by the mid-1930s, Japan was producing 150-horsepower gasoline engines.

The first gasoline railcar in Japan was operated in 1921 on the Yoshima Tramway in Fukushima Prefecture. This small railroad connected the little mining town of Yoshima in the Joban coal fields to the National Railway Joban Line. The use of gasoline railcars spread rapidly in the 1920s, beginning with small, short-distance runs and gradually extending out to middle-distance routes. Most gasoline railcars in Japan were operated in single units on private rural railroads, so the low-output engines could be installed on the car floor or on a hood. But gradually, most railcars were built with their engines mounted under the floor to allow maximum advantage of floor space for passenger service. Most engines were imported from the United States. The car bodies were built by small manufacturers like Matsui Seisakusho and Maruyama Sharyo, but by the end of the 1920s, they were being built by large manufacturers such as Nihon Sharyo, Kawasaki Sharyo, and Kisha Seizo.

The National Railways had been test-running gasoline railcars since 1929. In 1932 it began mass-producing the Kiha 36900 (name later changed to the Kiha 41000; "ki" refers to gasoline or diesel railcar and "ha" to third class), 139 of which were built by 1936. This model had a lower, narrower body than the standard passenger coaches of that time, its truck frames and trucks were simplified and of lighter weight. A 100-horsepower Japanese produced gasoline engine, highly rated for its reliability, was installed under the floor.

In 1933, 30 small Kiha 40000s were built with 100-horsepower engines capable of pulling one freight car on non-urban railroads. From 1935 to 1937, 63 large Kiha 42000s with 150-horsepower engines were built.

These gasoline railcars had mechanical power transmissions; they could not be multiple-unit controlled. Electrical and hydraulic power transmissions were test-constructed to overcome that deficiency, but the engineers were unable to come up with a satisfactory operating model before World War II.

Diesel engines were, initially, imported from Germany; domestic production began in the 1930s at Ikegai Ironworks and Niigata Ironworks, but the engines were never very widely used.

Small internal-combustion locomotives were built with gasoline and diesel engines and widely used, beginning in the 1920s, in some private railroads, factories, and river construction projects. A few of the locomotives were powered by diesel engines intended for marine use. The first large-scale locomotive of this type used by the National Railways was the DC11, a diesel-electric locomotive with 600-horsepower output imported from Germany in 1929. The DC10, a diesel-mechanical locomotive, also imported from Germany and of 600-horsepower output, arrived in Japan the following year. However, their mechanical complexity made them very difficult to operate and repair. A lot of problems also arose from taking these locomotives apart and putting them back together so many times; they no longer operated as originally intended. Domestic production of diesel locomotives was begun, but only a few were built. Japan's technical levels at the time were far behind those of Europe and the United States in producing high-output internal-combustion engines for general use, not to mention advanced internal-combustion engines for aeroplanes and ships.

Development of internal-combustion locomotives and railcars ground to a halt when the government instituted controls on oil in 1937.

Larger-sized Electric Railcars and Passenger Coaches and Partial-Steel Car-body Construction

In 1919, the National Railways started widening and heightening the basic passenger coach bodies it had been building since 1910, to bring them up to almost the same size as the European passenger coaches of the day. The new coach model was called the large-size basic passenger coach, and the previous one was renamed the mid-size basic passenger coach. All passenger coaches manufactured after 1920 were of the large-size type.

During the 1920s, greater interest was being shown in steel as a material for building large, durable, safe car bodies that could be used in fast trains. The private railroads in the metropolitan areas had quite early on begun to use cars with bodies made from steel. Coming off the assembly line in 1923, the 2-axled G car from Kobe Municipal Tram was Japan's first domestically built steel car. Strictly speaking, though, the car was not completely steel: its roof, inside panelling, and floors were wood, and thus it was called a partial-steel car. The first high-speed electric railroads to use partial-steel cars were Hanshin Kyuko Railway, Hanshin Electric Railway, and Keihin Electric Railway, in 1924. An all-steel car appeared in the following year. The National Railways began using its Moha 73200 (later named the Moha 30) partial-steel electric cars in 1926 and its Oha 44400 (later named the Oha 31) partial-steel passenger coaches in 1927. Generally, all electric, passenger, and internal-combustion railcars constructed after 1927 were partial-

Table 2. Number of passenger and freight cars owned

End of fiscal year	Passenger coaches				Freight cars
	Passenger coaches (without motive power)	Electric railcars	Internal-combustion railcars	Total	
1872	58			58	75
1882	240			240	503
	(1983) 47			47	101
1892	637			637	1,746
	739			739	2,819
1902	1,296			1,296	5,292
				3,537	15,861
1907	4,963	26		4,989	32,242
				677	1,367
1912	6,064	72	12	6,148	40,527
				4,047	4,056
1922	8,865	415	18	9,298	55,405
				8,137	9,478
1932	9,085	1,269	64	10,418	64,923
				11,101	13,348
1942	11,205	1,828	235	13,268	105,835
	2,038	8,572	456	11,066	12,484
1947	11,479	2,364	227	14,070	107,716
	1,851	7,365	277	9,493	10,211
1952	11,387	2,710	238	14,335	106,626
	886	9,429	266	10,581	10,865

1962	10,983	5,924	3,223	20,130	129,433
	589	13,100	315	14,004	9,366
1972	7,757	13,918	5,426	27,301	135,912
	171	15,661	217	16,049	4,096
1982	5,526	18,235	4,683	28,444	84,923
	172	18,083	202	18,530	1,936
1983	5,092	18,184	4,450	27,726	63,510
	178	18,857	182	19,217	1,589

Source: Harada Katsumasa, *Tetsudō no kataru Nihon no kindai* (The railroads and Japanese modernization), expanded and rev. ed., p. 244, table 8 (more recent data have been added).
Note: The upper row of the double sets of figures is for the National Railways, the lower row for the private railroads. The figures for private railroads include tram locomotives. Only the totals are given for passenger coaches up to 1932.

steel cars. ("Mo" refers to electric-motor car, "ha" to third class, and "o" to trailing passenger coach, weighing between 27.5 and 32.5 tons.)

The National Railways lengthened its standard passenger coach from 17 m to 20 m in 1929, and, in the following year, 20 m electric cars appeared. Most private railroads, however, were unable to switch over to 20 m cars because of the sharpness of the curves and other track limitations on their routes.

Private railroads in the Kyoto-Osaka-Kobe area began to use high-output electric motors during this period with several high-speed electric trains equipped with four 200-horsepower electric motors. These developments are attributable to the private railroads' need for faster express trains because they were all operating similar interurban services and the competition was growing fierce.

As the cars were converted from wood to steel, their cross-sections made larger, their bodies longer, they were also becoming much heavier because there were few attempts to reduce their weight. The weight increase was particularly noticeable in the first-class passenger coaches, which were being fitted with more luxurious appointments. The wooden large-size passenger coach was a three-axle bogie model weighing about 30 tons; but many partial-steel 20 m passenger cars weighed more than 40 tons; this meant much greater train weights and a need for more powerful engines to pull them.

Automatic Couplers and Air Brakes

With the exception of those in Hokkaido, Japanese trains were equipped with either screw or link couplers, compound coupler systems in which the connector link from one car is connected to the pintle on the next. The coupling operation required a lot of experience and was very dangerous, responsible for the injury, and even death, of many switchmen. Another problem was that the more cars that were coupled, the weaker the coupling was, and therefore the greater the possibility of uncoupling and accidents on steep grades.

The National Railways decided, in 1919, to begin using automatic couplers, but careful preparations for the change-over had to be made, and all couplers would have to be changed within a very short period. Railway officials had to procure the automatic couplers, most by import from the United States, the maintenance crews had to drill holes in advance and to fit all rolling-stock with housings for coupler attachment. The required number of couplers was delivered to all repair yards, but, since the freight cars were always on the move, from 1923 on, the cars ran with two sets of couplers binding the underframes until the day for replacement arrived. The repair crews practised the change-over procedures for days so that they could perform them quickly.

All couplers were changed over according to the following schedule: 17 July 1925 – Honshu and Shikoku (except for the isolated Kochi and

Tokushima lines); 20 July 1925 – Kyushu; 22–27 July 1926 – Kochi Line; 1–5 July 1927 – Tokushima Line.

Couplers on locomotives were changed over at the locomotive shop or at an assigned station on a night the locomotive was not in operation. Almost all passenger coaches scheduled for modification and reserve coaches were changed over at the shops from 1 to 10 July, 1925. Other rolling-stock was converted at a terminal station specified in advance. The freight cars, though, required the most work. All freight-train operations from 12 midnight to 12 midnight on the chosen day were stopped, the cars brought into the closest suitable station, and the coupler change started at 5 A.M. and ended at 7 P.M.

Automatic couplers were already being used in Hokkaido, but since they were installed on the cars at a position 660 mm above the surface of the rails, it was necessary to raise the couplers to make them compatible with the 880 mm standard on Honshu; this was done between 13 and 17 August 1924.

Private railroads that directly connected with the National Railways had to change couplers on their freight cars at this time, and the Railway Ministry provided financial assistance in completing the job.

The change to automatic couplers made the coupling and uncoupling operations safer and more efficient. The previous standard for number of tons of freight cars on the trunk lines had been 600–700, but the change-over raised that to 900–1,000 tons.

The introduction of air brakes was another important reform. Vacuum brakes were in general use on passenger trains before the 1920s, but freight trains had handbrakes. The decision was made in 1919 to adopt the direct air brake on all freight cars, and in 1921, studies and actual installation work began under the instruction of engineers from Westinghouse. The direct air brakes were installed first in Hokkaido and operation started in July 1925. By April 1927 freight trains in areas outside Hokkaido had begun using the brakes. The use of air brakes gradually spread, so that by 1930 three-fourths of all freight trains had brake cylinders attached. Installation on all freight trains was completed in 1933. Installation on passenger trains started in 1929 and was completed in July 1931.

Automatic couplers and air brakes, as well as increased locomotive size, were important technical innovations for increasing train speed and transport power on the trunk railroads.

The Development and Popularization of Express Trains

Japan's most prestigious train during the World War I period and after was the limited express (*tokkyu*) train that had consisted of first- and second-class carriages only and started running between Shimbashi and Shimonoseki in June 1912. But in July 1923, the first limited express train offering third class passenger service began round-trip operations. Long-distance travel was gradually falling within the means of a larger number of people. Although occurring in response to increased transportation demand, it was also a phenomenon closely related to the age of Taisho democracy. Observation and sleeping cars, however, were omitted from the third-class limited express.

The poor economic situation of the latter half of the 1920s brought a decline in revenues to the National Railways, which tried all kinds of new and different services in an attempt to get more freight and passenger customers. One such attempt was when the National Railways decided to give its limited express trains names rather than call them by numbers as in the past, so that a more popular image would be created and a larger segment of the public become acquainted with the express train services. To get the names, they started a contest open to everyone. When the results were announced, the winning names were assigned: the first- and second-class limited express trains would henceforth be known as *Fuji* and the third-class limited express trains would be *Sakura*. Subsequently, the limited express train running between Tokyo and Kobe that began services in October 1930 was named *Tsubame*.

The *Tsubame* had first- , second- , and third-class seats, and its speed reduced the more than 11-hour trip between Tokyo and Kobe to 9 hours. Overall speeds for the *Fuji* and *Sakura* were also increased at about this time. Faster speeds demanded fewer cars, two factors raising the demand for tickets on these trains. This overall increase in transport demand led to, in December 1931, the launching of an extra *Tsubame*, with only second and third classes, that would be operated for one round trip during peak passenger periods and would follow 10 minutes behind the original *Tsubame*. There were thus now four round-trip limited express trains running between Tokyo and Kobe.

Third-class sleeping-car trains began operating in February 1931. They were first used on express trains between Tokyo and Kobe and later hooked into the *Sakura* limited express trains in June of the same year. At first they provided no blankets and pillows, but a pillow service was started in 1934.

The rapid increase in limited express trains and their use by a wider public made the distinguishing of trains by class of car meaningless; the December 1934 opening of the Tanna Tunnel on the Tokaido Line between Atami and Numazu in Shizuoka Prefecture allowed greater speeds, and at the same time, a third class was added to the *Fuji* and a second class to the *Sakura*, so that all limited express trains had third-class coaches. The *Fuji* in particular took on the character of an international train by being connected through the Shimonoseki-Pusan ferry to the express train *Hikari* that ran between Pusan and Xinjing (Changchun) and to express trains on the Nagasaki Line that met with scheduled ships running between Nagasaki and Shanghai.

Demand for transport by limited express train continued to increase, necessitating the bringing into service of the new *Kamome* limited express between Tokyo and Kobe in July 1937. That brought to five the number of round-trip limited express trains on the Tokaido Main Line, including the unscheduled, seasonally operated *Tsubame*.

Improving the Trunk Lines

Japan's railroads of the Meiji period reflected the level of construction technology of the time, for there was a strong tendency to keep the number of tunnels and their lengths to a minimum. Consequently, even trunk lines had 25-per-mil gradients on many lines.

These steep gradients became more of an obstacle as transportation demand increased in the post–Russo-Japanese-War period. Several lines of steep gradience had been scheduled for improvement in the 1910s, but during the period under study, a switch was made to new lines in many areas to avoid the steep grades.

One of the largest improvement projects of this kind was on the Tokaido Main Line through the Hakone Mountains. At the time there was a series of 25-per-mil gradience in 50 km of the route skirting Hakone Mountain. To avoid steep grades a route was selected from Kozu through Odawara and Atami, under the Tanna Basin via a long tunnel, and then on to Numazu. Construction on this route started in 1916, with the digging of the giant Tanna Tunnel beginning in 1918. The building of the tunnel was scheduled at the start to take seven years, but it ran into many obstacles. The large amounts of spring water, solfataric clay, and geological faults presented difficult problems to man and machine – and then the site was hit by the northern Izu earthquake. All in all it took 16 years before the entire tunnel was ready. The full length of the double-tracked Tanna Tunnel, 7,841 m, was opened for service in December 1934. The completion of the tunnel reduced the route between Kozu and Numazu to 48.5 km and the steepest grade to 10 per mil, so that what took an express train 2 hours and 30 minutes to cover had now been cut to 1 hour and 20 minutes. It also increased by three times the length of trains that could be pulled on this route.

Construction on the Joetsu Line to shorten the distance between Tokyo and Niigata Prefecture started in 1918 and the entire line was opened in September 1931 with the completion of the single-tracked Shimizu Tunnel, 9,702 m long, then Japan's longest. The Joetsu Line drew Niigata Prefecture well within Tokyo's economic sphere.

However, even with the many improvements made during this period, there remained many lines where the gradients were at least 20 per mil, and, with the exception of the dual-tracked Tokaido Main Line, completed in 1913, and the San'yo Main Line between Iwakuni and Nijigahama, completed in 1930, almost all trunk lines were single-tracked.

The Development of Railway Ferries for Freight-Car Transport

Railway ferries operated by the National Railways in 1920 were the Aomori-Hakodate, Uno-Takamatsu, Miyajimaguchi-Miyajima, Shimonoseki-Moji, and the Shimonoseki-Pusan.

Except for the route between Shimonoseki and Moji, ordinary cargo-passenger vessels were used on these routes, and because the freight had to be reloaded from freight cars to ships or barges, freight would often get blocked up in the port. As transportation demand increased after the Russo-Japanese War, railroad ferries were seen as obstacles to smooth freight transport. Freight and passenger transport were already handled separately on the Shimonoseki-Moji (Komorie) route, and freight cars were carried on towed barges from 1911 on. But in this period, an overall improvement in transport efficiency was achieved using ferries that carried freight cars.

The first two self-propelled freight-car ferries, the 463 gross ton *Kammon Maru I* and *Kammon Maru II*, went into service in 1919 between Shimonoseki and Moji. There were eventually five of these ferries in operation on this route, which led in 1922 to the elimination of towed-barge service. All of these ferries were double-ended paddle-wheelers able to carry six cars loaded with 15 tons of freight each. Freight ferries continued in operation between Shimonoseki and Moji until 1942, when the Kammon Tunnel was completed and opened to rail traffic.

Freight ferrying by towed barge between Uno and Takamatsu started in 1921. The first self-propelled freight-car ferry, the *Uko Maru I*, went into service on this route in 1930, and one more ferry, the *Uko Maru II*, was added in 1934. Barges were operated here at the same time until 1943.

The difference in couplers on rolling-stock in Honshu and Hokkaido and the long distance of 61 nautical miles between Aomori and Hakodate made the route across Tsugaru Strait the last to put freight-car ferries into operation. In 1919, a programme was initiated for freight-car ferries coinciding with the plan to install automatic couplers on all rolling-stock in Honshu. Construction was completed in 1924 of four 3,400-gross-ton freight ferries, the *Shoho Maru*, *Hiran Maru*, *Tsugaru Maru*, and *Matsumae Maru*, that went into service in August 1925, immediately after the switch-over to automatic couplers in Honshu. These four ships became the prototypes for the Japanese railroad ferries of later years, their car decks running the entire length of the boat, about two meters above the loaded water-line, with an opening in the stern where freight cars were moved in and out. Passenger cabin decks were situated above and below the car deck. These ferries carried a total of 25 cars loaded with 15 tons of freight each, and their steam turbine engines, unusual for commercial ships of that day, gave a top speed of 17 knots. The increase in freight traffic made possible the putting into service of the freight ferries *Seikan Maru I* in 1926 and the *Seikan Maru II* in 1930, both of which had no passenger facilities. The two ships had the ability to carry 43 15-ton freight cars, a large capacity, but they were rather slow at 14 knots.

Since the railroads connecting with the Shimonoseki and Pusan (the Kampu Line) terminals ran on tracks of different gauge, no plan was ever seriously considered to ferry freight cars across the Tsushima Strait. As the demand for transport increased, however, larger and faster ferries were put into service on this line, until eventually it had not only the largest and fastest (over 20 knots), but the most luxurious vessels operating in coastal waters.

A railroad ferry service began between Wakkanai and Otomari (now Korsakov) as part of the railroad network connecting Hokkaido and Sakhalin (formerly Karafuto), but the different automatic coupler heights prevented freight-car ferrying. Standard passenger-cargo ferries were used, all of them with ice-breaking capability.

Note

1. A rail in which one metre of length weighs 37 kilograms. Measured in yards and pounds, this is a 75-pound rail (75 pounds per foot).

Roads

Hirofumi Yamamoto

Increase in Motor-Vehicle Imports and the Development of Domestic Production

The years from the Great Kanto Earthquake of 1923 to the outbreak of the Sino-Japanese War in 1937 mark a period in which policies of economic rationalization were sought to deal with the Great Depression and the economy moved rapidly into a wartime stance. The import of vehicles and parts during the period stimulated further progress in motorization and thus further progress in road transportation. Road-transport businesses were also quickly organized and integrated so that transport costs could be reduced and the building of the transport system completed. Motor vehicle transportation in Japan really began to thrive in the 1910s, particularly through the use of imported passenger cars, with hired cars, taxis, and even motorized buses appearing everywhere in the country around 1920. Not many lorries were in operation until the post-earthquake recovery period, but they showed their usefulness in emergency transport at that time. Ford- and General Motors-produced motor vehicles were now quickly beginning to supplant the European models previously imported. In 1925, Japan Ford set up a plant in Yokohama, and, in 1927, Japan General Motors built its plant in Osaka, all funds for which the companies provided themselves. The import of completed motor cars and the assembly of imported parts by these two giants overwhelmed the nascent native motor car makers and gave the foreign giants rule over the Japanese market until the mid-1930s (see tables 3 and 4). Damage from the 1923 earthquake and the incursion of foreign motor cars into the domestic market presented a series of crises for Japanese motor car manufacturers. Around 1930, to improve the balance-of-payments picture, the government adopted a policy designed to promote the domestic manufacture of motor vehicles through grants-in-aid for the production of lorries and buses designated as standard by the government. This provided the impetus for three powerful companies – Ishikawajima